THE

CHEMISTRY OF FIRE,

BY

LEWIS H. STEINER, M. A., M. D.,

PROFESSOR OF CHEMISTRY IN THE NATIONAL MEDICAL COLLEGE AND COLUMBIAN COLLEGE, WASHINGTON; LECTURER ON CHEMISTRY AND PHYSICS, COLLEGE OF ST. JAMES, &c. &c.

(FROM THE MERCERSBURG REVIEW.)

CHAMBERSBURG, PA.:
PRINTED BY M. KIEFFER & CO.
1855.

Digitized by the Internet Archive
in 2017 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/chemistryoffireb00ste

THE CHEMISTRY OF FIRE.

OBJECTS of a striking character are most apt to attract the attention of man, on account of their departure from the usual course of nature, or because they exhibit some seeming anomalous deviation from her laws. The phenomena of nature, which hourly take place, in and about him, generally fail to command his attention,—though he is ready to recognize the might of the great Ruler of all things, when bright flashes of lightning, accompanied with the pealing sound of its thunder appear in the skies above him. The little seed may show the wonderful powers possessed by its dormant vital force,—may send forth rootlets, which shall give the future plant a firm hold on the soil and enable it to gain sustenance from the same,—may develop the slender stalk and even grow up to the full maturity of a tree,—but these, being every-day occurrences, regular manifestations of the laws of the vegetable kingdom, elicit but little attention or admiration from man. Again, the animal! —comprising still more that is wonderful than the plant,—its very existence being a constant warring of the vital force against a dying tendency of its component parts,—the physiological paradox, that to have life we must have constant death,—the peculiar food needed to repair the effects of the wear and tear of the system, and the mysterious changes *it* undergoes before it can be fully adapted for this purpose,—the

regularity of the Circulation, bearing in one direction a vivifying current, and in another, one surcharged with noxious principles,—the Respiration, conveying the peculiar substance which vivifies to the one current of the circulation and removing that which is detrimental to life from the other,—the closing scene of life, when the power, which presents these very mysteries as proofs of its presence, leaves the vital frame and although there may remain,

> "Before Decay's effacing fingers
> Have swept the lines where beauty lingers,"

the rapture of repose, yet the decay of the particles, which previously formed the body, making it now loathsome to those who formerly delighted in its company:—all these are allowed to occur daily without exciting more than a passing notice from the world.

Even the principle, which we call *Life*, underlying the mysteries of the plant and manifesting its presence in it by *growth*, or in the animal adding to this manifestation that of feeling and instinct, or in man, the higher power of intellectuality and will,—even this fails to attract a modicum of that attention its importance demands.

All these afford striking examples of the consummate wisdom of their Creator, on account of their harmonious adaptation to the ends, for which they were created. They are examples of the normal operations of nature. Constant familiarity with them has caused us to forget, or at least to overlook them in our daily reflections, and it is only when some remarkable deviation *from* the rule presents itself,—some Aztec or Giant,—that we pause to consider *what* constitutes the rule, and to investigate the nature and extent of the deviation.

There are many things also connected with the physical phenomena of nature, which rarely receive attention from us. Among these can be mentioned the four so-called elements of the Ancients, from which they supposed all matter was created. In the *Earth*, they saw the stable basis of the whole, applying the name to everything of a solid nature found in the planet on which we live; in the *Air*, they recognized a simple fluid which appeared to penetrate all space; in *Water* and *Fire*,

two antagonizing principles, always warring against each other. This division of matter, erroneous though it be, was first proposed by Aristotle. It has challenged investigation, which has resulted in great additions to our knowledge. We do not propose to follow such investigations in the present article, but merely wish to examine the *Chemistry of Fire*,—to discuss the wonders of the simple process which we designate by this name, and the nature of the substances essential to it under ordinary circumstances. In doing this, a wide field will be opened to us, abounding in the richest treasures of science, from which we may glean some material that shall clearly show, *all is not only mysterious that occurs at rare intervals*, nor is everything or process, "weary, flat, stale or unprofitable," which belongs to the daily operations of nature.

Heat is the great repulsive force of nature. Matter of a seeming everlasting character is forced, from its compactest form, to become mobile, and to allow movement among those particles, which were bound by the strongest force of cohesion, one to the other. The Ancients, with all their innate reverence for the forces of nature, and their disposition to attribute them to the direct agency of Divinities, hailed Fire as the mightiest of the gods,—watching with admiration the spark, as it was fanned into a small flame, at first flickering, contending with feeble power for the mastery, then gaining additional force from the food on which it was feeding, and finally springing upwards embracing the combustible material in its lambent course. The bright flickering of the flames, as they played in the hearth, dispensing comfort and cheerfulness, while the chilling blasts of the wintry wind were heard howling in the darkness of the night, seemed to them like a god in his kindest and most gracious mood; while the lurid flames of the volcanic eruption, or the vivid flashes of the heaven's electricity, seemed like that same god in his angriest and most vindictive mood. Quite early indeed did the poetic mind of man detect the indispensability and importance of Heat, in the mild and vivifying rays of the sun, as it kindly enticed forth, from the hidden recesses of the seed, the radicle and plumule which constitute the vegetable, and in that animal warmth, without which life itself cannot be.

During the Middle Ages, when chemical research was in its infancy, and all investigations were found nugatory without the aid of fire, it was an agent idolized by the Alchemists. They hoped by its means to expel the moisture, supposed to be inherent to Quicksilver,—and which, when removed, would leave behind the precious metal—Silver—one of the objects of their toilsome researches. By it alone, also, they expected to obtain those potent extracts which should have the wonderful power of transmuting all things into Gold,—and which should allow Science the actualization of the power that Mythology had placed in the hands of Midas.

Fire is worshipped at the present day. The Persians are known to adore flame as a spiritual essence, constituting the life-giving and life-sustaining force of nature. Indeed this idea, with some little modification, is acknowledged as true by modern science. Though it is not considered the *primal* force, yet, under the direction of omnipotent power, it is the mightiest of all the agents selected to manifest this power. For notwithstanding Fire is to be considered as the result of intense chemical action, yet, as its immediate effect is Heat, we may look upon it as entering into the composition of all matter and determining its condition,—bodies being solid because they lack the necessary amount of heat to give them fluidity, and liquids because they have not sufficient heat to give their intimate particles elasticity inter se. In such a view, although we fail to determine exactly what may be the nature of heat or fire, we prepare ourselves to investigate the sources from which it comes.

We find it streaming along with rays of light from the sun, and, by the different angles with which it strikes the earth, producing that pleasant change of the seasons, which makes up the year,—causing the grateful breezes of the spring which woo forth, from their hiding places, sweet birds and fair flowers;—the fiery blasts of the summer's Sun, and the chilling winds of the winter. It comes also from the interior of our planet, where, philosophers teach us to believe, there exists a raging fire, producing heat of such intensity, that all matter, the refractory metals, the primary state of the geologist—the

enduring granite—are all in a state of fusion,—the cohesion, that binds their particles so tightly together, as they are found on the surface of the earth, being unable to withstand the intensity of this heat. In this way we learn what may be the cause of the existence of volcanoes and mighty Geysers, which seem to project their contents forth, as from a boiling chaldron in the depths of the earth.

Heat determines the peculiar physical condition of matter. We need only refer here, by way of illustration, to the fact that, although water remains as a liquid with us at almost all seasons of the year, yet, in winter, the diminution of the external temperature (that is, an abstraction of heat,) reduces it to the condition of a solid, whereas at a depth of little over two miles into the solid crust of the earth it is probable it would fly off into the aeriform condition and be only known as steam. And this power of regulating the volume of a body, by means of heat, is not exaggerated when we are told that it could be determined with precision "what amount of heat would be required to evaporize all the water on the globe," and "how much would be necessary to cause the whole globe itself to become vaporiform." Such calculations could be surely made, as the laws which regulate the condition of bodies with reference to heat, are fixed and determinate.

Heat is also produced by mechanical action,—driven, as it were, from a body by a condensation of its molecules, when friction or percussion is employed. Here, scientific explanation was preceded by the practice of the savage. The latter had known, for centuries before science was able to explain the rationale of the process, how, by the friction of two pieces of wood together, he could produce sufficient heat to ignite them. Many a council fire had been lighted by him in this way, and many a poor victim's life became a prey to flames which the tormentors had thus produced.

In the animate kingdom, Heat is bound up in some mysterious way with life itself; and, most important for our present purpose, it is developed by chemical action, with every phase of which, there is either a reception or loss of heat. No action, within the wide range of chemical affinity, is possible without

its presence. Under this head, we include combustion, where the action of heat manifests itself with such intensity as to form the phenomenon, called fire.

For the production of Fire, or *rapid* combustion, it is essentially necessary that there should be substances which are in their very nature combustible, and one which is capable of supporting combustion. The mysterious laws, which regulate the combination of these, in the process, require that certain and definite quantities should be present, and that the combinations, thus formed, should always be alike in their constitution. Thus when wood is burned, for example, it is a fixed law, that it should be converted into products having always the same composition,—a composition which is as exactly determinable by weight as mathematical accuracy can be,—and as true to itself under *like* circumstances, as the scales of justice are in affording to man the perfect equipoise of reward or punishment for the moral weight of his actions. Here indeed in the very beginning of our examination into the nature of the Chemistry of Fire, we learn something with regard to the composition of matter, which gives us an illustration, to use the words of Griffiths, "of the Scriptural truth, that a just weight and measure are the Lord's; that a just weight is His delight; that He comprehended the dust of the earth in a measure, and weighed the mountains in scales and the hills in a balance."

If the results of combustion were not of such a fixed character, there would be no harmony in nature's laws,—that music which, though inaudible to the mere sensualist, sounds through nature and all her works,—swells in the roaring of the wind and gently whispers in the murmuring of the breeze,—forms its accords of dulcet sweetness in the movements of the planets, and calls to its aid everything that exists, whether it be animate or inanimate,—that music would be, we say, at best but the jingling of discordant sounds, devoid of all the enchanting sweetness which now forces us to recognize it as the most positive and convincing proof that it is the voice of the Lord of all.

A most important requisite to rapid combustion is the presence of an element capable of supporting it. Such an element

should exist in large quantities all over our earth, as Fire is required not only for the protection of man from the inclemency of winter, but also to aid him in all those operations, which an advanced condition of civilization demands shall be carried on through the aid of Fire. We need not refer to those processes, which the Chemist, in his Laboratory, shut out from the noise and tumult of the busy world, carries on for the purpose of scrutinizing the mysteries of nature, and, if possible, forcing her to give the key which shall reveal her hidden secrets; we need not refer to the many long days he spends in watchfulness by his Laboratory fires, justifying his claims to the title of "the Philosopher by Fire." It is not necessary to enter the quiet retreat of the student. Let us go forth into the workshops of the land, where the stalwart arm of the mechanic moulds, by the aid of fire, the refractory metals and forces them to assume the thousand varied forms his ingenuity suggests; let us watch him as he constructs, by its means, that wonder of mechanism—the steam engine—the stoutest and most useful servant to execute man's commands, and to perform with readiest alacrity the duties assigned it; let us examine the various forms which *iron* has been made to assume under the masterly skill of the workman; how, at the present time, we can judge of the position of any nation in the scale of civilization by its knowledge of the thousand useful purposes this metal can be made to serve; how, by the aid of Fire are constructed of iron, the tools of the artisan, the anvil of the smith, the trowel of the mason, even the delicate knife of the surgeon, and the multifarious machines which the farmer needs for tilling the soil, or in making its products available: all these show that if "iron may be regarded as the greatest material source of national intelligence and industry," Fire is the agent by which all its applicability to man's designs is fully and completely drawn out.

The element, *essential to ordinary combustion*, is a gaseous body, called Oxygen. This combines with the elements of the combustible and forms new compounds. The presence or absence of flame depends on the intensity of this combination. The *two principal constituents of all combustible bodies*, are

substances called Carbon and Hydrogen. It will be interesting to see, to *what extent*, these three elements, so necessary to fire, are distributed over Nature, and also *why it is*, that the two which form the essential constituents of all ordinary combustions, are the only elementary substances especially fitted for this purpose, on account of the peculiar changes they undergo, which result either in the formation of a substance not injurious to life, or of one which, from its peculiar constitution as a gas, is readily mingled with the great ocean of the atmosphere and by vast dilution also rendered innocuous.

Oxygen is the most widely distributed of all the elements, forming, in its combinations, at least two thirds of the whole earth; entering into the structure of organic bodies; into the composition of the waters which lave great continents, with their dashing billows or gently meander through grassy meadows; and into the formation of those mighty mountains, which, upreaŕing their summits as if in defiance of the wasting effects of time, give the beholder the idea of illimitable duration. And we find it not only in these, but in the atmosphere, as an indispensable constituent, penetrating all its parts, and bearing the same ratio to the other constituents wherever we investigate its composition. We are unconscious of its presence, because that presence is required for the perfect carrying on of the functions of life; and thus, its condition, though apparently passive, retains in ever fresh activity all the world about us.

The process of Respiration in the animal, depends on the presence of Oxygen, and is at most but an arrangement by which the system can be supplied with sufficient quantities of it to combine with and burn out, as it were, such particles as are no longer of utility in the system. The process is necessary for this *slow combustion* in the system. Every motion of the body requires the removal of some portion of the living frame work. The same law holds here, as in Mechanics, "that for any given effect, there is a consumption, a change of state, of a definite proportion of some material element." This change of state is produced, in the body, by the slow combustion in the capillaries—the furnaces of the animal system—of

certain substances which are composed mostly of carbon and hydrogen in varying proportions. All acts of life, then, are mysteriously connected with the presence of this bland supporter of combustion. Wherever we find vital force, we find the physical condition of its presence is, that there must be consumption of some part of the frame work in which it dwells. And this holds good throughout the whole range of organic life, whether we view it as the monad, of ephemeral existence, or in man with his reflecting mind and responsible soul. Throughout the whole range, the distinctive marks, which separate vitality from mere mechanical action, are dependent on the change of matter which is brought about by its combination with Oxygen gas; and although we are unable to perfectly explain, by theory, yet we know, experimentally, that the relation existing between vital force and the consumption of organic particles in the living body, is a direct one. The laborer who depends on the work of his hands for the support of himself and family, requires, in the pursuit of his daily avocations, the consumption of more organic particles, than the student whose physical labor is light; the former feels this keenly in practice, as the hours for his meals approach, and with an appetite, altogether paradoxical to the latter, eats with zest the amount of food necessary to make up for this previous consumption. This consumption of particles goes on as long as life lasts. The demands are, that, for every vital act, there must be a coincident death of some particle belonging to the system in which the vitality is manifested. All parts waste away under the influence of Oxygen, since to have action, energy, life in the whole, such sacrifice of the parts must take place; and, if, as is very briefly expressed by a scientific writer of the present day, "no means are at hand for repairing these daily and hourly losses, the individual perishes—dies more slowly, but not less surely, than by a blazing pile, burned at a low temperature,"—all the constituents of the body disappearing in succession, till at last "the substance of the brain becomes attacked," and reason tottering on its seat, "madness and death close the scene."

But though means should be at hand to repair these losses,

if the element which produces them be diminished, we shall find that, with each successive respiration, the demonstrations of vitality will be diminished, until at last the whole series of results, which demonstrate its existence, will close and death take place. The actions essential to vitality are destroyed, because the combustion necessary for their production is checked by the absence of the Oxygen. (It will be understood we are all this time not endeavoring to show that the vital force is synonymous with chemical action; but that the former manifests its presence in this way, and selects combustion as the means of generating physical force.) If we confine an animal in any place, where the atmosphere is not renewable from the great ocean of air around us, every breath it draws, deprives this atmosphere of its life-sustaining power; the animal languishes and dies. The system is crowded with the results of previous combustion of its particles. There are no means by which they can be removed. The blood flows sluggishly along the sides of vessels, through which it should course gaily. Stagnation of the blood takes place and with the checking of its current, there is a checking of life itself.

If this experiment be tried in a closely-confined room, in which a crowded assembly has been collected, weariness and lassitude are produced, and each one feels, as he leaves the room and breathes the pure air, the vast difference between the free reception of this grateful stimulus and the limited quantity he has only been allowed to inhale in the room. The respiration of the crowd has gradually removed the stimulating material which is required to keep up a slow combustion in the body, in order that the conditions of vigorous health may be preserved. An examination of the composition of the atmosphere of a close room with a crowded audience, before and after a Lecture in the Sorbonne, showed that as much as five proportions of Oxygen had been removed by this means in the space of an hour.

As life cannot be preserved under circumstances of confinement, in an atmosphere containing a limited quantity of Oxygen, so active combustion or fire cannot take place. In a vacuum it will be immediately extinguished. Where the sup-

ply of Oxygen is limited, the flame will become dim, and flickering faintly will soon cease. Hence the same element is indispensable to both; while allowed free access to the living being, or to the burning substance, we have the phenomena of life or of fire so long as the material on which it feeds is supplied it. In the one case this is determined by a law which regulates the existence of the organic being; in the other, by the amount of material afforded for the combustion.

But if life be dependent on the presence of Oxygen, and if combustion cannot take place unless it is present, it is a fair and rational supposition, that where the quantity of this element is increased beyond the normal amount, combustion would increase in vividness and rapidity, and the operations of the animal system would be carried on with increased vigor and activity. Such a supposition is proven to be true, when the chemist experiments with it, in a state of purity, as to its effect on life and combustion. When an animal is immersed in an atmosphere of pure Oxygen, the effects of the latter are too stimulating, and the result is inflammation and speedy death. Hence it forms only a small portion of the atmosphere, being there diluted by the presence of four times its weight of another gas, whose office seems to be only that of a diluent. If the atmosphere were composed of pure Oxygen, the animal creation would speedily perish from over stimulus; the phenomena of life would be produced in so heightened a degree that death would speedily close them. In the words of another, "as a candle burns brighter in Oxygen gas, and is more quickly consumed, so in this gas the flame of life would be more vivid, but would be sooner burned out."

Notwithstanding the constant demand made on the atmosphere for Oxygen, there has been no change in the composition of the former, since the first appearance of human life on the face of our earth. An analysis of the air at present would furnish nearly, if not quite, the same component parts, as existed in it centuries ago. By suitable provisions of Providence its deterioration has been prevented, and the element, so essential to the preservation of life and to combustion, is now as widely distributed as in the remotest period of history, and will

so continue for ages in the future. Independent of the means existing in the vegetable kingdom for supplying it, a French chemist has made a curious calculation, which shows that "the earth might be peopled with a thousand million of men, and animals equivalent to three thousand million of men, and yet these would not together consume, in a century, a weight of Oxygen equal to that of 16 cubes of copper, 3.273 feet by the side, while the air would contain 134.000 of these; and indeed that it would require ten thousand years for this number to produce any sensible effect on the great body of the air," so that chemical or electrical analysis could detect the change of composition.

Many agencies are at work to prevent an accumulation of impure substances in the atmosphere, freeing it from the impurities which have been combined with its Oxygen, and thus liberating the latter. Among these must be mentioned, as of first importance, the vegetable kingdom. In the Laboratory of the leaves, under the chemical influence of the solar beam, the purification of the atmosphere goes steadily on, from the first greeting the plant receives from the sun's rays in the morn until, in the borders of twilight, the last lingering ray leaves it for the purpose of visiting other plants in other climes. During all this time the chemistry of nature is at work. The Laboratory of the leaf is busied in furnishing supplies of Oxygen for the maintenance of animal life.

> "From its inmost cells, each leaflet pours
> In vital currents through its myriad pores,
> To renovate the air, by tempest hurl'd
> From pole to pole, around a freshen'd world."

But Oxygen does not only exist in the gaseous or liquid form; it also enters in the composition of the geological strata, which form the firm basis of our earth; into the constitution of the solid silica, and there, though immured, as it were, within rocky walls, still possessing the same properties as when floating in the passing breeze or forming a constituent atom in the foaming billow. Its range of combination with other substances is quite extensive, required by each of the three divisions of nature, and its place not to be supplied by any other of the sixty

two elemental eonstituents of matter. This universality of diffusion, shows the wisdom involved in its selection, as the universal supporter of eombustion. If the world should be deprived of it, retaining, however, its present eonstitution, the higher animals would eease to exist, and vegetable matter of a rank eharaeter would eover the earth. Where beauty and graee are now seen to deek the meadow and hill side,—dark, colored vegetation, with a lurid glare, would alone meet the view. Creation would lose the highest manifestation of its Creator's power in the faet, that its master-piece (man himself) could not live to enjoy, and, as it were, bring out the significance of the whole. The grand end and objeet of the whole, the glorifieation of the Maker, would be prevented, by the impossibility of a living soul being present to render thanks and honor for the varied beauties of ereation.

We shall find by refleetion that our theme is not devoid of its poetry as well as of its general interest. Who has not felt his imagination awakened, as he has watched the open fire on his hearth, and in its changing flame, pietured weird figures of terror, or those charming phantasies, in which the mind at times delights to revel? Has not the light, daneing on the wall, ehasing fitfully the darkness away, obedient to the longing wishes of the dreamer, assumed the forms of the distant and the loved, while all unconseious of the present, he has again lived over joyous days in the past, when from unbeelouded skies, the sun of peaee and happiness shone brightly over his path, or when, perhaps, mid storms of unrest, he battled against the might of oppression and injustiee. There is a witching sweetness thrown around these hours of revery; a joyous freedom from the trammels whieh bind men to things of time and sense; a bliss whose greatest elimax is attained amid the fullest serenity of the human mind.

We have seen that the element essential to fire, as its supporter, is widely spread throughout nature; the nature of the two prineipal elements of all eommen eombustibles remains yet to be examined, as well as the nature of the produets whieh result from this process: the last of whieh subjeets will eonelusively show, that no other two elements would have answered for the purpose in the present constitution of matter.

The element, *Hydrogen*, is widely diffused throughout the organic and inorganic divisions of nature. The substance which contains it in largest quantity, is water, of the volume of which it constitutes two-thirds. Its distribution is, therefore, immense; the vast distances, separating continent from continent, are occupied by this bland production of nature. In gushing streams it pours forth from the mountain rock, or in little rills it trickles down the hill side, bearing life and vigor to the parched vegetation of the plain; it comes, in spring, in gentle showers from the vapory clouds ranging in the sky above us, or from the storm clouds of summer, amid the play of heaven's electricity, it dashes upon the earth. View it in the placid lake, when no breeze ruffles the smooth and tranquil surface; the depths mirroring forth the forest trees that fringe its borders, giving the semblance of forests below, for the sportive amusement of old Neptune's subjects, and when perchance the swiftly-fleeting clouds reflected from its surface, as they chase one another across heaven's blue expanse, may be the only seeming disturbance to its tranquility.

View it again, when its waves have been lashed into the fury of a giant, under the influence of the driving storm; see how that consummate piece of man's handicraft, the steam-ship, with all its might, is rendered as helpless as an infant in the hands of a giant. Contemplate it with wonder, as under the direction of the bold Fireman it checks the ravages of the agent we are now considering, when crackling flames are fast destroying the beautiful works of man, and imminent peril is threatened to the unconscious slumberer; when the terrifying cry of *Fire* meets his ear in the dead of night, and the suffocating smoke, with the glaring flames, falls upon his opened eyes; when death, by the most awful torments known to man, seems grinning his ghastliest smile in the midst of the bewildering wall of flame which surrounds him; and then, see the conflict between the flames and the torrents of water, how, at first, the water seething and vaporizing, seems to lose all power when in contact with the destructive element, until torrent succeeding torrent, the imprisoned sufferer awaiting death, sees destruction removed from his path; the way is opened and life again smiles

cheeringly at him. Here we see water, as a mild agent, perfectly passive; again a giant in strength and activity; and again coping with the destructive agent of nature and gaining the mastery.

But these are not all the purposes to which it is devoted in the mysterious economy of nature. It enters into the composition of all that has life, constituting the basis of those fluids which permeate all parts of animated structure. Deprive the latter of the presence of water, and there is only left a moiety of its former weight and none of its characteristic life. Even in man, however, it finds an use, independent of the mere support of the animal system, since the very language, with which extreme grief or joy is expressed by him, requires the employment of—Tears. In the chaste description of an English author,* the tear in the beautiful eye of a child may thus be traced:

"It was distilled from the primeval seas, it rose into the air, formed a cloud in the dark drapery of heaven, and was returned to water the rose and fertilize the corn-field. It then passed through the veins and arteries of the earth, bubbled up in the crystal spring, passed in the blood through that innocent little heart, and comes now the unbidden advertisement of a child's sympathy."

The traveller over the scorching sands of the great desert, deprived of water, suffers agonies unutterable, and gladly hails even the mirage,—all-deception as he knows it to be—thinking that by feasting his eyes on the sight of purling brooks he can banish, for the time, the agonies of his thirst. And the idea of this species of suffering is intensified in the highest degree when the instructive parable of Holy Writ sets forth to us the tortures of another world as of such a character that "not a drop of water can be obtained to cool the parched tongue."

But in this very water there is, as already stated, the element essential to combustion, united by close chemical affinity with Hydrogen—one of the two principal components of all ordinary combustibles; and the burning of the latter wherever

* Dream of Geology, 66.

found, if a sufficent quantity of Oxygen be present, again results in the formation of water. And thus we can imagine the immense amount of aqueous vapor thrown, in this way, daily into the atmosphere; how the balance is kept up between the organic and inorganic world, since vegetables absorb this water from the air and the soil in which they are planted, retain it as the means of communicating, throughout their branches and leaves, the richly-elaborated substances which form new structure, and yet, on being exposed to the action of fire they give up this water again to the great store-house, from whence their constant draughts have removed it.

The Hydrogen of a combustible in burning forms the blandest and least injurious of all the products of nature. How could art or science, with all the aid the discoveries of a century have furnished them, have selected any substance, any element that could have answered half so well, as regards its wide distribution throughout the vegetable kingdom, the ease with which it combines with the supporter of combustion and the innocuous products that result from such combination? Is this not a wonderful illustration of the wisdom of that creative power which made a process, in all its parts, so well adapted for the preservation as well as the protection of animal life?

If the combustion of the element Hydrogen results in the formation of water, the latter substance should be found constituting a portion of the atmosphere, which envelops our earth. Experiment justifies such a conclusion. There is always an appreciable amount of watery vapor in the atmosphere, intimately bound up with it, and yet capable of being demonstrated even by mechanical pressure, so that an English experimenter actually made its presence manifest, in the driest condition of the air, by using a pressure of thirty thousand pounds to the square inch. To prevent an accumulation that would be disastrous in its consequences to life, we find that, by changes of temperature, this moisture is condensed, and, along with the vapor which rises from the surface of the great ocean, it descends then to the earth in the grateful showers of spring, the rains of summer, or the snow and hail of our winter. Thus it goes on its round of duty, ministering to the wants of men

in a thousand ways, preserving a species of equilibrium in the great organization of nature.

Intimately combined with organic structure, Hydrogen may wait for a thousand years, the action of that chemical process which shall cause its union with Oxygen, and yet, during all that time, passive in character, it would indicate no semblance of the power which lies within it, nor would it lose this power in the slightest degree. When the moment arrives for the union of the two gases, combustion takes place, without leaving behind a product that could injure the most delicately constructed plant or the finest nervous system of the animal.

Let us suppose Sulphur had been the element selected to enter into the composition of ordinary combustibles. We know it will burn most freely,—will unite with the general supporter of combustion. But what would be the result? Would the products be innocuous to life, to say nothing of their actually being productive, after a time, of growth in the vegetable and being essential to the existence of the animal? Experience tells us, No! A gas of an offensive odor, destructive to all vegetable colors, bleaching the variegated shades of nature's garb, destructive to the vegetable and deadly to the animal, would be the consequence. Respiration would be impossible under such circumstances. Instead of the picturesque beauty of nature, a blighted scene would present itself; instead of the myriads of beings, teeming with life which cover the plain, swim in the water or float in the air, there would be no life,—but the earth would be one vast Golgotha, where all that had lived, breathed and suffered would be gathered in death from the pestiferous effects of this deadly gas. Nature would lose her very significance, since *without life* her highest and noblest meaning would be lost,—her grandest end and design would not be reached.

We must now hasten on to the consideration of the second substance, which enters into the composition of our combustibles. This is a solid substance called Carbon. Hydrogen, in burning, affords very little light; where illumination is required, Carbon must be added, which, from the heated condition it attains before it can be consumed and converted into

the gaseous form, produces almost the entire illuminating power of every burning substance. It forms a still larger proportion of the constitution of combustibles than Hydrogen. The consideration of its origin, place in nature and influences on the progress of civilization, would require far more space than is allotted us in this article,—but would afford an opportunity for presenting, in a connected form, some of the most attractive objects of study.

It is found largely distributed over both the organic and inorganic kingdoms, though originally belonging to the former. It is removed from a gaseous constituent of the atmosphere, called Carbonic Acid; this undergoes decomposition under the chemical effects of the light of the sun, the Carbon is retained for the structure of the plant, while the Oxygen, which in combination with it forms this acid gas, is given off again to enter the atmosphere. This process goes on wherever there is vegetation. The distribution of the element Carbon, though obtained by this comparatively slow process, is very great, and presents it in many different forms. If we divest wood of its Hydrogen and a number of inorganic substances taken up from the soil, we have left behind Carbon, in the form of *Charcoal*, constituting from fifteen to twenty six per cent of the original weight of the dried wood. Again, we find it laid up, as a species of mineral, in the great vaults of the earth, for the uses of mankind, and *Anthracite* is the name given to another form of Carbon. We find it in the material which the artist uses to give permanence to the forms that an educated perception of the beautiful produce in his mind, and Carbon is here known as *Plumbago*. Under another form, not black and repulsive in its appearance, but resplendent in its lustre, the object of grasping avarice and the delight of gay votaries of fashion, it appears as the brilliant *Diamond*; the synonyme of grandeur and high state; the Koh-i-noor among objects of wealth and beauty. Yet in all these forms, whether as Charcoal or Anthracite, which hide under a black and repulsive exterior, the material that under the effects of combustion is able to give activity to the steam engine in its application to the thousand purposes for which the ingenuity of man has used it, from the

distribution of the products of commerce by the mighty steamship, to the publication of the products of mind by that enormous lever of the world, the printing press; or in the form of the Diamond, which bedazzles the eyes of the spectator as it crowns the brow of beauty; under these varied forms its constitution is always the same. When exposed to heat it will become incandescent—throw off light and heat, and burn; the coal no more readily burning when kindled in our grates, than the diamond when heated in an atmosphere of pure Oxygen. The products of this combustion, being gaseous, are speedily removed by dilution in, and mixture with the great mass of the atmosphere. If this were not so, "the solid results of combustion," says Farraday, "the ashes, so to speak, would have fallen like a mantle on every earthen object; light could neither have emanated nor been seen; the economy of nature would have been embarrassed, clogged for want of agencies to remove the results of combustion, and all living things would have died.*

But whence come the immense coal-beds, which underlie many districts of this country? How can it be possible that such an immense quantity has been collected from the vegetable kingdom, that one hundred and thirty three thousand one hundred and thirty two square miles of coal formation are supposed to exist in the United States, and eleven thousand eight hundred and fifty nine in Great Britain?

It is now proven beyond the shadow of a doubt, that Anthracite was originally formed by vegetable structure. The microscope examines its intimate construction and finds undoubted vegetable cellules, and the exact moulds or impressions of plants are also often found in the thickest portion of its structure. Modern science has also shown that these impressions might be produced in an artificial way; that by exposing leaves, imbeded in clay, to a red heat, a carbonaceous product was obtained very similar to the fossil leaf presented by nature in her coal beds. But the character of the vegetation which produced the fossil leaves, the immense periods of time, through which

* Farraday's Lectures, pp. 277.

the vegetable matter must have slowly accumulated and the forces by which it was completely carbonized (the other constituents in the mean time having been removed by slow combustion,)—these are subjects, on which we can speculate only with the greatest wonder, considering them the results of gigantic power.

If Carbon is separated from the atmosphere by the vegetable creation, it is manifest that the composition of the atmosphere in the ante-historic periods of the world, must have differed from its composition at present, as such enormous beds of coal could not have been separated from it without producing great changes in its constitution, and an atmosphere largely impregnated with Carbonic Acid, could not have permitted any human being to have lived and flourished on the globe, since large quantities of this gas are fatally pernicious to life. Hence, without straining the argument at all, we must consider this whole process of Carbonification to have taken place during that period of time, which, in the simple and sublime language of the Mosaic record of the creation, is called "the evening and the morning of the third day,"—before man was created, before the perfecting of Creation had been accomplished.

The forms, however, of the plants of that period, learned by us in our examinations of the impressions found in our coal strata, were different, both in kind and size, from the forms of those which belong to the present period of our history. Where science even detects a resemblance in some of the vegetables of the present day to those enduring *Lithographs*, which nature has made of the plants of her infancy, the resemblance seems more like that of the Lilliputians of Gulliver's first voyage, as compared with the giant Brobdignagians of his second. As to the ante-historic period of the coal formations, we may truly say there were "giant plants in those days." If we could transport ourselves back, beyond the period of our own records, to that period, much would be found to astonish, yea, even to bewilder our unaccustomed eyes,—a wilderness of vegetable growth altogether unknown at present, would present itself, and in those giant solitudes, where vegetation was unchecked by the limitations of the present day, the beholder

would gaze with the stupifying astonishment that an inhabitant of some distant planet would probably exhibit, if on a visit to our earth. The author of the "Old Red Sandstone," in his imaginary visit to this geological period, has well depicted, and, we think, not with extravagance, what would probably have met the eye. On the banks of streams, bearing "seeds and ferns and cones of the pine of gigantic size," he sees "an amazing luxuriance of growth. Scarce can the current make way through the thickets of aquatic plants that rise thick from the muddy bottom; and though the sunshine falls bright on the upper boughs of the tangled forest beyond, not a ray penetrates the more than twilight gloom that broods over the marshy platform below. The rank steam of decaying vegetation forms a thick blue haze, that partially obscures the underwood. Deadly lakes of Carbonic acid gas have accumulated in the hollows; there is a silence all around, uninterrupted save by the sudden splash of some reptile fish that has risen to the surface in pursuit of its prey, or when a sudden breeze stirs the hot air, and shakes the fronds of the giant ferns, or the catkins of the reeds. The wide continent before us is a continent devoid of animal life, save that its pools and rivers abound in fish and mollusca, and that millions of the infusory tribes swarm in the bogs and marshes. Here and there too, an insect of strange form flutters among the leaves. It is more than probable that no creature furnished with lungs of the more perfect construction, could have breathed the atmosphere of this early period and lived."

From this luxuriant growth of vegetables the material was obtained for the vast coal formations already noticed. They grew to their full height, and then made way for similar plants of the same species. The stratum of vegetable deposit thus increased through thousands of years, it may be, to its present thickness, when by some sudden revolution of nature, some mighty inundation, bearing along with it material from distant hills, this vegetable deposit was covered up from sight. In the process of time, a like meadow, rich in these tropical productions, may have been formed on this deposit, and another rich stratum of vegetable material obtained, to be covered up, like

its predecessor, by some great revolution in nature. Then came the *Carbonization.* Under the joint action of immense pressure and moisture, a species of smothering spontaneous combustion ensued; the other elements of the plants were removed and the Carbon was left behind, forced into the compact mass we know as *Coal.* In passing through coal regions, especially where rail-road cuttings have been made, the coal strata will be often seen divided from each other by deposites of clay, slate or aluminous rocks, and thus, from their position, forcibly supporting the idea just expressed as to their formation. They look like tomb-stones placed over a race in the vegetable world, now past and gone; but they are suggestive to the human mind of the idea that He who made them must have possessed the very sum of wisdom, thus to cause the very decay and death of the plants of an ante-diluvial world to minister to the wants and comforts, as well as to aid the energies of those destined to flourish on the same world, in post-diluvial times.

The vegetation of this particular period answered another grand end in the economy of the universe; it prepared the way for the reception of a higher order of animate existence, by removing from the air that very substance which would have been fatal to all of that class; it made the earth habitable for beings created in the fifth period in the course of creation—"the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind," and also man made "in the image of the Deity and after His own likeness." The mind is lost in wonder, when it attempts to apprehend the grandeur of the process; extending through ages, preparing the way for the entrance on the stage of Time of the greatest wonder of all—MAN, himself. All the gorgeous visions which imagination has pictured as belonging to the wonders of Fairy land; all the gigantic works of fabled Genii sink into insignificance, when compared with this wonderful reality.

But to return to our subject; Carbon, whether furnished from these immense coal-beds or from the wood of the forests of our own times, in the process of combustion, unites quietly with Oxygen and forms a gaseous substance, already mentioned as Carbonic Acid. Now though this product is not as harmless to life as the water which is formed by the combustion of

Hydrogen, yet on account of a property peculiar to gases, which enables them to diffuse themselves through each other in despite of their gravity, until their noxious properties have become extremely attenuated, this Carbonic Acid gas, though much heavier than air, is diluted to so great an extent that it is rendered innocuous. It is as free from odor as water itself, and its swift dilution by the atmosphere prevents any ill effects from its presence. This very aptitude for dilution, and its freedom from any deleterious power or odor, when diluted, constitutes the special merits of Carbon as a combustible. If it were an odorous gas, like that produced by burning Sulphur, already noticed, although it might be diluted so as to have its poisonous properties prevented from acting on the system, yet the odor would render the atmosphere altogether intolerable.

Just as common combustion forms Carbonic Acid because there is sufficient Oxygen present for this purpose, so also that slow combustion which takes place in the system, produces Carbonic Acid, which is thrown off, by every expiration from the lungs. And this illustrates the innocent character of this gas, when present in a diluted condition. It comes into contact with the delicate tissue of the lungs and produces no injury; is continually bathing their minutest cells without altering their structure. There is no substance, except Carbon, which would answer these purposes; serving through slow combustion in delicate capillaries, to keep up the heat of the animal, and forming a product which passes quietly out of the system without injury, in the slightest degree, to its most intimate structure.

The amount of Carbon thrown off from the body, through the process of respiration, is almost incredible; making as much as $13\frac{3}{4}$ ounces per day from the adult. This is removed from the air again by the vegetable kingdom, which detains the Carbon and throws off pure Oxygen for the support of the animal. The animal and vegetable thus act in opposite ways on the constitution of the atmosphere; the former throws off that gas, which if collected in large quantities around it would be detrimental to its life; while the latter absorbs this, extracts its poisonous properties and sends forth the element which is so im-

portant to life. Thus the two portions of creation mutually contribute to each others preservation and mutually exhibit the grand compensating laws of nature.

What process invented by man, could exhibit such an admirable adaptation of means to the end, not constructed as our processes always are, of a complicated nature, employing various external adjuvants to produce the desired effect, but the relation between the means and the end being *immanent.* The elements are so intrinsically adapted to each other; the results are so little calculated to injure the slightest and most delicate created being; the whole process is one grand exhibit of an Omnipotent power, which shows its Omniscience no less in the destruction of matter than in its primal creation; a subject for study, which must impress one full as much with the idea of an overruling Providence, as the grandeur of the storm, or the glorious beauties of the firmament, when studded with its myriads of heaven's luminaries, the brightly shining stars.'

If we have succeeded in showing that one of the most familiar processes of nature combines as much that is wonderful, as those which, on account of their departure from her usual course, are more apt to attract the attention of man, our design has been accomplished in this article; our promise fulfilled that we would find, in this subject, some material which would clearly show, all is not only mysterious that occurs at rare intervals, nor is everything or process, "weary, flat, stale or unprofitable," which belongs to the daily operations of nature.

The ancients had a glimpse into the true nature of this process, and, as has been referred to by Scoffern, in one of their poetic myths, they have shadowed forth the same idea that science has since developed into the form of a full and satisfactory theory. The Phœnix having accomplished the end of her existence, mounted the funeral pile, fanned the flames which were to consume her body, but not to destroy one particle, since from the very ashes she rose again clothed in all the vigor and buoyancy of youth, regenerated from the deformities and decrepitude of age. The flames did not *destroy* matter, but presented it in a new form. There was here strong belief, veiled in poetic imagery, in the indestructability of matter,

when Fire even was shown to be unable to accomplish this result. And thus, in fact, must it ever be, so long as the present laws, governing created matter, are permitted to have power over it; and *when* this power ceases, and only *then*, shall Matter yield to anything like a destructive tendency,—Fire being selected by the Creative Power as the grand agent for destroying "the old things" of this World, and making way for the more brilliant and more durable things of that New World, whose limits can only be embraced in the idea of Eternity.